

**WHAT IS CLAIMED IS:**

1. A photomask comprising, on a transparent substrate:

a semi-shielding portion having a transmitting property against exposing light;

5 a transparent portion surrounded with said semi-shielding portion and having a transmitting property against the exposing light; and

an auxiliary pattern surrounded with said semi-shielding portion and provided around said transparent portion,

wherein said semi-shielding portion and said transparent portion transmit the exposing light in an identical phase with respect to each other, and

10 said auxiliary pattern transmits the exposing light in an opposite phase with respect to said semi-shielding portion and said transparent portion and is not transferred through exposure.

2. The photomask of Claim 1,

15 wherein said transparent portion is in the shape of a rectangle with a side smaller than  $(0.8 \times \lambda \times M)/NA$ , wherein  $\lambda$  indicates a wavelength of the exposing light, and M and NA respectively indicate magnification and numerical aperture of a reduction projection optical system of a projection aligner.

3. The photomask of Claim 2,

20 wherein said auxiliary pattern is a line-shaped pattern and has a center line thereof in a position away from the center of said transparent portion by a distance not less than  $(0.3 \times \lambda \times M)/NA$  and not more than  $(0.5 \times \lambda \times M)/NA$ .

4. The photomask of Claim 3,

25 wherein said auxiliary pattern has a width not less than  $(0.05 \times \lambda \times M)/(NA \times T^{0.5})$  and not more than  $(0.2 \times \lambda \times M)/(NA \times T^{0.5})$ , wherein T indicates relative transmittance of said auxiliary pattern to said transparent portion.

5. The photomask of Claim 2,

wherein said auxiliary pattern is a line-shaped pattern and has a center line thereof in a position away from the center of said transparent portion by a distance not less than  $(0.365 \times \lambda \times M)/NA$  and not more than  $(0.435 \times \lambda \times M)/NA$ .

5 6. The photomask of Claim 5,

wherein said auxiliary pattern has a width not less than  $(0.1 \times \lambda \times M)/(NA \times T^{0.5})$  and not more than  $(0.15 \times \lambda \times M)/(NA \times T^{0.5})$ , wherein T indicates relative transmittance of said auxiliary pattern to said transparent portion.

7. The photomask of Claim 1,

10 wherein said transparent portion is in the shape of a line with a width smaller than  $(0.65 \times \lambda \times M)/NA$ , wherein  $\lambda$  indicates a wavelength of the exposing light, and M and NA respectively indicate magnification and numerical aperture of a reduction projection optical system of a projection aligner.

8. The photomask of Claim 7,

15 wherein said auxiliary pattern is a line-shaped pattern and has a center line thereof in a position away from the center of said transparent portion by a distance not less than  $(0.25 \times \lambda \times M)/NA$  and not more than  $(0.45 \times \lambda \times M)/NA$ .

9. The photomask of Claim 8,

20 wherein said auxiliary pattern has a width not less than  $(0.05 \times \lambda \times M)/(NA \times T^{0.5})$  and not more than  $(0.2 \times \lambda \times M)/(NA \times T^{0.5})$ , wherein T indicates relative transmittance of said auxiliary pattern to said transparent portion.

10. The photomask of Claim 7,

25 wherein said auxiliary pattern is a line-shaped pattern and has a center line thereof in a position away from the center of said transparent portion by a distance not less than  $(0.275 \times \lambda \times M)/NA$  and not more than  $(0.425 \times \lambda \times M)/NA$ .

11. The photomask of Claim 10,  
wherein said auxiliary pattern has a width not less than  $(0.1 \times \lambda \times M)/(NA \times T^{0.5})$   
and not more than  $(0.15 \times \lambda \times M)/(NA \times T^{0.5})$ , wherein T indicates relative transmittance of  
said auxiliary pattern to said transparent portion.

5 12. The photomask of Claim 1,  
wherein said auxiliary pattern includes a first auxiliary pattern that is adjacent to a  
different auxiliary pattern spaced by a given or smaller distance with said semi-shielding  
portion sandwiched therebetween and a second auxiliary pattern that is not adjacent to a  
different auxiliary pattern spaced by said given or smaller distance with said semi-  
10 shielding portion sandwiched therebetween, and

said first auxiliary pattern has a smaller width than said second auxiliary pattern.

13. The photomask of Claim 12,  
wherein said first auxiliary pattern includes a first pattern that is away from the  
adjacent different auxiliary pattern by a distance G1 and a second pattern that is away from  
15 the adjacent different auxiliary pattern by a distance G2, and

in the case where  $(0.5 \times \lambda \times M)/NA > G1 > G2$ , said second pattern has a smaller  
width than said first pattern, wherein  $\lambda$  indicates a wavelength of the exposing light, and M  
and NA respectively indicate magnification and numerical aperture of a reduction  
projection optical system of a projection aligner.

20 14. The photomask of Claim 13,  
wherein a difference between the width of said first pattern and the width of said  
second pattern is in proportion to a difference between the distance G1 and the distance G2.

15. The photomask of Claim 2, further comprising, on said transparent  
substrate:

25 a second transparent portion adjacent to said transparent portion and spaced by a

given or smaller distance,

wherein said auxiliary pattern includes a first auxiliary pattern disposed in an area sandwiched between said transparent portion and said second transparent portion and a second auxiliary pattern disposed in the other area, and

5        said first auxiliary pattern has a smaller area than said second auxiliary pattern.

16. The photomask of Claim 15,

wherein said given distance is  $(1.3 \times \lambda \times M)/NA$ .

17. The photomask of Claim 7, further comprising, on said transparent substrate:

10        a second transparent portion adjacent to said transparent portion and spaced by a given or smaller distance,

wherein said auxiliary pattern includes a first auxiliary pattern disposed in an area sandwiched between said transparent portion and said second transparent portion and a second auxiliary pattern disposed in the other area, and

15        said first auxiliary pattern has a smaller width than said second auxiliary pattern.

18. The photomask of Claim 7, further comprising, on said transparent substrate:

a second transparent portion adjacent to said transparent portion and spaced by a given or smaller distance,

20        wherein said auxiliary pattern includes a first auxiliary pattern disposed in an area sandwiched between said transparent portion and said second transparent portion and a second auxiliary pattern disposed in the other area, and

said first auxiliary pattern has a smaller area than said second auxiliary pattern.

19. The photomask of Claim 17,

25        wherein said given distance is  $(1.15 \times \lambda \times M)/NA$ .

20. The photomask of Claim 2,

wherein said transparent portion is close to a different transparent portion spaced by a distance of a given range at least along a first direction and is not close to a different transparent portion spaced by a distance of said given range at least along a second direction,

said auxiliary pattern includes a first auxiliary pattern disposed around said transparent portion along said first direction and a second auxiliary pattern disposed around said transparent portion along said second direction, and

said first auxiliary pattern is farther from said transparent portion than said second auxiliary pattern.

21. The photomask of Claim 20,

wherein said given range is from  $(1.15 \times \lambda \times M)/NA$  to  $(1.45 \times \lambda \times M)/NA$ .

22. The photomask of Claim 2,

wherein said transparent portion is close to a different transparent portion spaced by a distance of a given range at least along a first direction and is not close to a different transparent portion spaced by a distance of said given range at least along a second direction,

said auxiliary pattern includes a first auxiliary pattern disposed around said transparent portion along said first direction and a second auxiliary pattern disposed around said transparent portion along said second direction, and

said first auxiliary pattern is closer to said transparent portion than said second auxiliary pattern.

23. The photomask of Claim 22,

wherein said given range is from  $(0.85 \times \lambda \times M)/NA$  to  $(1.15 \times \lambda \times M)/NA$ .

24. The photomask of Claim 7,

wherein said transparent portion is close to a different transparent portion spaced by a distance of a given range at least along a first direction and is not close to a different transparent portion spaced by a distance of said given range at least along a second direction,

5        said auxiliary pattern includes a first auxiliary pattern disposed around said transparent portion along said first direction and a second auxiliary pattern disposed around said transparent portion along said second direction, and

      said first auxiliary pattern is farther from said transparent portion than said second auxiliary pattern.

10        25. The photomask of Claim 24,

      wherein said given range is from  $(1.0 \times \lambda \times M)/NA$  to  $(1.3 \times \lambda \times M)/NA$ .

      26. The photomask of Claim 7,

      wherein said transparent portion is close to a different transparent portion spaced by a distance of a given range at least along a first direction and is not close to a different transparent portion spaced by a distance of said given range at least along a second direction,

15        said auxiliary pattern includes a first auxiliary pattern disposed around said transparent portion along said first direction and a second auxiliary pattern disposed around said transparent portion along said second direction, and

20        said first auxiliary pattern is closer to said transparent portion than said second auxiliary pattern.

      27. The photomask of Claim 26,

      wherein said given range is from  $(0.7 \times \lambda \times M)/NA$  to  $(1.0 \times \lambda \times M)/NA$ .

      28. The photomask of Claim 1,

25        wherein said transparent portion is in the shape of a line,

said auxiliary pattern is disposed in parallel to said transparent portion along a line direction of said transparent portion, and

said transparent portion has a line end protruded beyond said auxiliary pattern by a given or larger dimension along the line direction.

5           29. The photomask of Claim 28,

wherein said given dimension is  $(0.03 \times \lambda \times M)/NA$ , wherein  $\lambda$  indicates a wavelength of said exposing light, and M and NA respectively indicate magnification and numerical aperture of a reduction projection optical system of a projection aligner.

30. The photomask of Claim 1,

10           wherein said transparent portion is in the shape of a line,

said auxiliary pattern includes a pair of first auxiliary patterns disposed in parallel to said transparent portion along a line direction of said transparent portion and sandwiching a line center part of said transparent portion and a pair of second auxiliary patterns disposed in parallel to said transparent portion along the line direction and  
15           sandwiching a line end part of said transparent portion, and

a distance between said pair of second auxiliary patterns is larger by a given or larger dimension than a distance between said pair of first auxiliary patterns.

31. The photomask of Claim 30,

20           wherein each of said pair of second auxiliary patterns has a length along the line direction of  $(0.03 \times \lambda \times M)/NA$  or more, wherein  $\lambda$  indicates a wavelength of said exposing light, and M and NA respectively indicate magnification and numerical aperture of a reduction projection optical system of a projection aligner.

32. The photomask of Claim 30,

25           wherein said given dimension is  $(0.03 \times \lambda \times M)/NA$ , wherein  $\lambda$  indicates a wavelength of said exposing light, and M and NA respectively indicate magnification and

numerical aperture of a reduction projection optical system of a projection aligner.

33. The photomask of Claim 1,

wherein said transparent portion is formed by exposing said transparent substrate,

said auxiliary pattern is formed by depositing, on said transparent substrate, a first

5 phase shift film that causes, in the exposing light, a phase difference in an opposite phase with respect to said transparent portion, and

said semi-shielding portion is formed by depositing, on said first phase shift film,

a second phase shift film that causes, in the exposing light, a phase difference in an opposite phase with respect to said first phase shift film.

10 34. The photomask of Claim 1,

wherein said transparent portion is formed by exposing said transparent substrate,

said auxiliary pattern is formed by trenching said transparent substrate by a depth

for causing, in the exposing light, a phase difference in an opposite phase with respect to said transparent portion, and

15 said semi-shielding portion is formed by depositing, on said transparent substrate, a semi-shielding film that transmits the exposing light in an identical phase with respect to said transparent portion.

35. The photomask of Claim 1,

wherein said transparent portion is formed by exposing said transparent substrate,

20 said auxiliary pattern is formed by trenching said transparent substrate by a depth for causing, in the exposing light, a phase difference in an opposite phase with respect to said transparent portion, and

said semi-shielding portion is formed by depositing, on said transparent substrate,

a metal thin film that transmits the exposing light in an identical phase with respect to said

25 transparent portion.



36. The photomask of Claim 1,

wherein said auxiliary pattern is formed by exposing said transparent substrate,

said transparent portion is formed by trenching said transparent substrate by a depth for causing, in the exposing light, a phase difference in an opposite phase with respect to said auxiliary pattern, and

said semi-shielding portion is formed by depositing, on said transparent substrate, a phase shift film that causes, in the exposing light, a phase difference in an opposite phase with respect to said auxiliary pattern.

37. A pattern formation method using the photomask of Claim 1, comprising the

steps of:

forming a resist film on a substrate;

irradiating said resist film with the exposing light through said photomask, and

forming a resist pattern by developing said resist film after irradiation with the exposing light.

38. The pattern formation method of Claim 37,

wherein oblique incident illumination is employed in the step of irradiating said resist film with the exposing light.

39. A mask data creation method for creating mask data for a photomask including a mask pattern formed on a transparent substrate and a transparent portion of said transparent substrate where said mask pattern is not formed, comprising the steps of:

determining an internal distance and a width of outline shifters on the basis of a desired exposed region of a resist formed by irradiating said resist with exposing light through said photomask;

providing said transparent portion inside said outline shifters;

setting said transparent portion as a CD adjustment pattern;

providing a semi-shielding portion for transmitting the exposing light in an identical phase with respect to said transparent portion in such a manner that said transparent portion and said outline shifters are surrounded with said semi-shielding portion;

5            setting said outline shifters as phase shifters that transmit the exposing light in an opposite phase with respect to said transparent portion;

             predicting, through simulation, a dimension of a resist pattern formed by using said mask pattern including said phase shifters and said semi-shielding portion; and

             when said predicted dimension of said resist pattern does not accord with a  
10        desired dimension, deforming said mask pattern by deforming said CD adjustment pattern.

             40. The mask data creation method of Claim 39,

             wherein the step of determining an internal distance and a width of outline shifters includes a sub-step of changing said width of said outline shifters in accordance with a distance between said outline shifters.

15            41. The mask data creation method of Claim 39,

             wherein the step of determining an internal distance and a width of outline shifters includes a sub-step of changing said internal distance of said outline shifters in accordance with a close relationship between desired exposed regions.